
PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Evaluate Whole System Effects On Migration And Survival Of Juvenile Salmon

BPA project number: 20011

Contract renewal date (mm/yyyy): ☐ Multiple actions?

Business name of agency, institution or organization requesting funding
Oregon Cooperative Fish and Wildlife Research Unit

Business acronym (if appropriate) OCFWRU

Proposal contact person or principal investigator:

Name	<u>Carl B. Schreck</u>
Mailing Address	<u>Dept. of Fisheries and Wildlife, OSU; 104 Nash Hall</u>
City, ST Zip	<u>Corvallis, OR 97331</u>
Phone	<u>(541)737-1938</u>
Fax	<u>(541)737-3590</u>
Email address	<u>Carl.Schreck@orst.edu</u>

NPPC Program Measure Number(s) which this project addresses
5.0B.3, 5.0E, 5.7A.6, 5.8, 5.8A.2, 5.9A.1, and 7.1A.1

FWS/NMFS Biological Opinion Number(s) which this project addresses
Relevant 1995 Federal Columbia River Power System (FCRPS) BiOp RPA measures are:
VIII.A(1,5,6), VIII.A.13.c, VIII.A.13.e, and VIII.A.13.f

Other planning document references

Short description

Our goal is to understand how salmon smolts may be managed to minimize loss in the Columbia River estuary. Physiological impacts during outmigration may affect behavior and survival in the estuary. Tissue sampling and radiotracking will be used.

Target species

Juvenile spring/summer chinook salmon

Section 2. Sorting and evaluation

Subbasin

Ocean/estuary, Lower Columbia Mainstem, Lower Mid-Columbia Mainstem, Lower Snake Mainstem

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
<input checked="" type="checkbox"/> Anadromous fish <input type="checkbox"/> Resident fish <input type="checkbox"/> Wildlife	<input checked="" type="checkbox"/> Multi-year (milestone-based evaluation) <input type="checkbox"/> Watershed project evaluation	<input type="checkbox"/> Watershed councils/model watersheds <input type="checkbox"/> Information dissemination <input type="checkbox"/> Operation & maintenance <input type="checkbox"/> New construction <input checked="" type="checkbox"/> Research & monitoring <input type="checkbox"/> Implementation & management <input type="checkbox"/> Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Document behavior and survival of transported and run-of-the-river chinook salmon through the estuary to the near-shore ocean environment	a	Tag spring/summer chinook smolts with standard and depth-sensitive radiotags and track using various radiotelemetry techniques
		b	Evaluate the effect of run-of-the-river migrant stock origin on migration and survival
		c	Document avian predation rates on radiotagged fish in the estuary
		d	Measure or determine physicochemical characteristics of the river and estuary in relation to migrating chinook salmon
2	Determine the relationship between fish condition (physiological indicators of fish quality) and migration behavior, physicochemical characteristics of estuary, predation susceptibility, and survival	a	Determine pre- and post-migration physiological status of transported and run-of-the-river chinook smolts at Snake and Columbia River mainstem dams
		b	Match physiological data with radiotracking data to see relationships between condition and behavior/survival
		c	Determine smoltification status of

			individual radiotagged fish and compare to subsequent behavior and survival
		d	Perform direct tests of the relationship between smoltification, bacterial kidney disease, saltwater entry behavior, and saltwater survival in a controlled situation
		e	Develop and validate a computer model incorporating all of the factors associated with smolt survival in the estuary as measured by returning adult spawners

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	10/1999	9/2001	Annual variation assessed	Yes	65.00%
2	10/1999	9/2001	Annual variation assessed	Yes	35.00%
				Total	100.00%

Schedule constraints

ESA permitting may constrain schedule.

Completion date

September 2001

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel	2 Research Aides, 2 Grad. Students, and 6 Seasonal Aides	% 31	125,880
Fringe benefits	Rate varies from 1-52% of wages, depending on position	% 8	33,334

Supplies, materials, non-expendable property	Hydrolab	%2	10,200
Operations & maintenance	Includes radiotags, flight time, boat charter, model validation, datalogger upgrade, sample analysis	%27	109,305
Capital acquisitions or improvements (e.g. land, buildings, major equip.)			0
NEPA costs			0
Construction-related support			0
PIT tags	# of tags: 0		0
Travel	Includes field housing and vehicles	%4	17,500
Indirect costs	43% for 9 months and 26% for 3 months, excluding Hydrolab and tuition	%23	93,019
Subcontractor			0
Other	Tuition (2 for 3 terms)	%2	11,460
TOTAL BPA FY2000 BUDGET REQUEST			\$400,698

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount (\$)
USGS-Biological Resources Division	15% PI's time	%6	30,000
Oregon State University	Administrative Assistant	%4	20,000
Total project cost (including BPA portion)			\$450,698

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	\$381,219			

Section 6. References

Watershed?	Reference
<input type="checkbox"/>	Blackburn, J. and W.C. Clarke. 1987. Revised procedure for the 24-hour seawater challenge test to measure seawater adaptability of juvenile salmonids.

	Can. Tech. Rep. of Fish. and Aquat. Sci. 1515:1-35.
<input type="checkbox"/>	Foster, L.B. and R.T. Dunn. 1974. Single-antibody technique for radioimmunoassay of cortisol in unextracted serum or plasma. <i>Clinical Chemistry</i> 20:365-368.
<input type="checkbox"/>	Goede, R.W. and B.A. Barton. 1990. Organismic indices and an autopsy-based assessment as indicators of health and condition in fish. <i>American Fisheries Society Symposium</i> 8:93-108.
<input type="checkbox"/>	Johnson, S.L., R.D. Ewing, and J.A. Lichatowich. 1977. Characterization of gill (Na+K+)-activated adenosine triphosphatase from chinook salmon, <i>Oncorhynchus tshawytscha</i> . <i>J. Exp. Zool.</i> 199: 345-354.
<input type="checkbox"/>	Redding, J.M., C.B. Schreck, E.K. Birks, and R.D. Ewing. 1984. Cortisol and its effects on plasma thyroid hormones and electrolyte concentrations during seawater acclimation in yearling coho salmon, <i>Oncorhynchus kisutch</i> . <i>Gen. Comp. Endocr.</i> 56:146-155.
<input type="checkbox"/>	Schreck, C.B., L.E. Davis, and C. Seals. 1996. Evaluation of procedures for collection, bypass, and transportation of outmigrating salmonids, Objective 1: Migratory behavior and survival. Draft Annual Report 1996, MPE-96-10. USACE, Walla Walla, WA.
<input type="checkbox"/>	Schreck, C.B., L.E. Davis, and C. Seals. 1997. Evaluation of migration and survival of juvenile salmonids following transportation. Draft Annual Report 1997, MPE-95-3. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.
<input type="checkbox"/>	Schreck, C.B., S. Kaattari, L.E. Davis, C.E. Pearson, P.A. Wood, J.L. Congleton. 1993. Evaluation of the facilities for collection, bypass, and transportation of outmigrating chinook salmon. Annual Report 1993, JTF-92-XX-3. USACE, Walla Walla, WA.
<input type="checkbox"/>	Schreck, C.B. and T.P. Stahl. In Prep. Evaluation of migration and survival of juvenile salmonids following transportation. Draft Annual Report 1998, MPE-W-97-4. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.
<input type="checkbox"/>	Ward, D.L. and L.M. Miller. 1989. Using radiotelemetry in fisheries investigations. Oregon Department of Fish and Wildlife (Fish Division) Information Reports No. 88-7.

PART II - NARRATIVE

Section 7. Abstract

The goal of this study is to obtain information that will allow us to make recommendations concerning how outmigrating salmon smolts may be managed while passing through the Columbia River hydropower system to minimize the subsequent loss of fish in the Columbia River estuary or nearshore ocean. Migration through reservoir and dam complex and transportation may have physiological impacts on smolts that affect their

behavior and survival once they reach the estuary and have survival consequences after early ocean entry. A critical point for survivorship appears to be where freshwater meets saltwater; our hypothesis is that behaviors, affected by physiology, affect smolt vulnerability to avian predators or lead to maladapted fish in the ocean. Thus, our efforts will be concentrated in the lower estuary of the Columbia River.

We will determine the physiological status (smoltification, general well-being, and disease) by sampling fish at Snake and lower Columbia River dams. Behavior of the fish will be assessed by telemetry in the lower estuary and will establish sources of mortality. Salinity preference and challenge experiments in a controlled setting will also be conducted to determine willingness of the fish to enter the ocean and compare behavior of barged and run-of-the-river radiotagged chinook. The effects of smoltification, disease, and stress of outmigrating juveniles on returning adult spawning populations will also be assessed through a computer-based population model. Field work will be conducted for two years to assess annual and seasonal variability.

Section 8. Project description

a. Technical and/or scientific background

The success of run-of-the-river (ROR) and transported smolts depends on the performance of the fish and capacity to successfully enter the ocean following release or passage past Bonneville Dam, the last dam in the Columbia River hydropower system before ocean entry. Post-hydropower system performance of the fish is a function of the quality of the fish, which is itself determined by the condition of the fish and the effect of the hydropower system (dam passage or barge transportation) on migration. Condition of fish when they reach the dam is extremely variable in terms of the general quality and health of individuals as well as in their state of smoltification. There is not only variation over the course of the run but also among individuals collected at any one time. How fish respond to management activities such as passage through dams or transportation is also variable. Our prior research suggests that this variation in fish quality is reflected in the ability of juvenile salmonids to perform various tasks, such as migration through the lower Columbia River and successful entry into the ocean.

Prior research has found that 10-30% of radiotagged juvenile chinook salmon are taken by piscivorous birds in the Columbia River estuary (Schreck *et al.*, 1996, 1997; Schreck and Stahl, in prep.). If this percentage extends to all migrants, then the total number of Columbia River yearling spring chinook taken by birds near the mouth of the river may have important impacts on outmigrating populations. It is not known what factors determine the vulnerability of migrating juvenile salmonids to bird predators, although fish behavior in the estuary clearly has the potential to increase or decrease the likelihood of being eaten. For example, those individuals who swim higher in the water column, or linger in areas containing many birds, may be more at risk. A number of factors relating to fish health and development (smoltification) have been shown to influence the behavior of juvenile salmonids, and by extension, survival. In addition, avian predator colony location,

which is will be managed to decrease smolt predation, may affect predation rates on outmigrating smolts; the effects of any management decisions regarding avian predators on smolts should therefore be studied.

Further, we postulate that the quality of migrants reaching the lower Columbia River (by either barge or in-river migration) relates to subsequent behavior and predation mortality. Fish quality may particularly relate to delays in seawater entry in the lower Columbia estuary. Such delays could result in more predation by increasing the amount of time the migrants spend in the freshwater lens, where the fish are exposed to large concentrations of birds due to the relatively shallow nature of the freshwater lens. Smoltification, disease, and stress status may all influence the amount of time a fish might be “trapped” in the freshwater lens. Although physiological condition influences behavior, the exact relationship between fish quality indices and behavior is not always intuitive. It has been demonstrated that seawater entry behavior may lag weeks behind physiological readiness to enter seawater as determined by saltwater challenge tests; such tests may be deceptive in that they measure the ability of smolts to enter seawater, but not the likelihood that they actually will do so.

We have already researched the migration of yearling chinook between Bonneville Dam and into the estuary (Schreck *et al.*, 1993, 1996, 1997; Schreck and Stahl, in prep.), which most yearling chinook successfully migrate. We also know that migration behavior of juvenile salmonids is influenced by river conditions such as flow (a function of dam discharge) and tidal stage. A critical area that remains unexplored is at the mouth of the river; we have limited information concerning detailed migration behavior of juvenile chinook salmon into saltwater. Increased understanding of smolt behavior at the freshwater/saltwater interface, which is miles long, is needed to determine what may be done to minimize rates of avian predation and limit forced saltwater entry of under-developed fish. Data should be collected in multiple years to account for annual variability that characterizes the Columbia River system. Another area which remains unexplored is how survival into saltwater ultimately affects returning spawner populations. An existing life-history model for salmonids will be developed and validated for the outmigrating juvenile stage. It will then be used to predict adult populations and effects of management decisions concerning the hydropower system and other areas of concern such as avian predators. Once the relationship between fish quality and behavior, as affected by river and estuary conditions, is understood, the opportunity exists to manage the migration of juvenile salmonids through the Columbia Basin hydropower system in such a way that their subsequent survival is maximized.

b. Rationale and significance to Regional Programs

The condition of juvenile salmonid migrants is affected by the structures, reservoirs, and river and fish management procedures they encounter during migration; these effects influence the subsequent survival of the fish. This research will provide information that will clarify the relationship between fish quality and migration behavior, as well as the effects of avian predator management decisions on smolt predation rates. With this

information, it becomes possible to manage the migration of juvenile salmonids through the Columbia Basin hydropower system in such a way that later survival of migrants is maximized. Relevant FWP measures are: 5.0B.3, 5.0E, 5.7A.6, 5.8, 5.8A.2, 5.9A.1, and 7.1A.1. Relevant 1995 Federal Columbia River Power System (FCRPS) biological opinion reasonable and prudent alternatives (RPA) measures are: VIII.A(1,5,6), VIII.A.13.c, VIII.A.13.e, and VIII.A.13.f.

c. Relationships to other projects

This research has no connections to current Bonneville projects.

d. Project history (for ongoing projects)

This is a new Bonneville proposal.

e. Proposal objectives

Our two primary, related hypotheses that will be tested by all of our research and related objectives and tasks are:

H₀: Physiological condition does not affect behavior or survival.

H₀: Behavior does not affect vulnerability to avian predation.

1. Document behavior and survival of transported and run-of-the-river chinook salmon through the estuary to the near-shore ocean environment.
 - a. Tag spring/summer chinook smolts with standard and depth-sensitive radiotags and track using various radiotelemetry techniques.
 - b. Evaluate the effect of run-of-the-river migrant stock origin on migration and survival.
 - c. Document avian predation rates on radiotagged fish in the estuary.
 - d. Measure or determine physicochemical characteristics of the river and estuary in relation to migrating chinook salmon.
2. Determine the relationship between fish condition (physiological indicators of fish quality) and migration behavior, physicochemical characteristics of estuary, predation susceptibility, and survival.
 - a. Determine pre- and post-migration physiological status of transported and run-of-the-river chinook smolts at Snake and Columbia River mainstem dams.
 - b. Match physiological data with radiotracking data to see relationships between condition and behavior/survival.
 - c. Determine smoltification status of individual radiotagged fish and compare to subsequent behavior and survival.
 - d. Perform direct tests of the relationship between smoltification, bacterial kidney disease, saltwater entry behavior, and saltwater survival in a controlled situation.
 - e. Develop and validate a computer model incorporating all of the factors associated with smolt survival in the estuary as measured by returning adult spawners.

f. Methods

Objective 1. Document behavior and survival of transported and ROR chinook salmon through the estuary to the near-shore ocean environment. Radiotelemetry will be used to assess the survival to saltwater and migratory behavior at the freshwater/saltwater interface of hatchery-reared yearling spring chinook that have been tagged and which are both transported via barge (tagged at lower Granite Dam) and remain in-river (tagged at Bonneville Dam) past Snake-Columbia River dams. The proportion of fish reaching saltwater will be measured, as well as the number of individuals likely taken by piscivorous birds in the estuary. Pressure-sensitive radiotags will also be used to document the depth at which yearling chinook salmon migrate, which may be affected by smoltification and delay the entry into saltwater, thus influencing the vulnerability of migrants to some species of birds. Water characteristics will be measured in relation to smolt migration. The effect of stock origin on migration and survival will be assessed by radiotagging PIT-tagged sorted fish collected at McNary Dam. All spatial data (locations, migration routes, depth, water measurements) will be taken with GPS equipment and entered into GIS for presentation, organization, and analysis.

Task 1a. Tag spring/summer chinook smolts with standard and depth-sensitive radiotags and track using various radiotelemetry techniques. Migration behavior and survival of transported and ROR yearling hatchery-reared spring chinook in the Columbia River estuary will be examined via biotelemetry. Radiotagged fish will be tracked in the lower estuary (below the Astoria Bridge) following release downstream of Bonneville Dam, to establish their post-release movement and survival into saltwater.

Radio transmitters will be implanted into fish 12 to 24 hours prior to departure of transport barges from Lower Granite Dam (Ward and Miller, 1989). Run-of-the-river fish will be collected at the Bonneville Dam Powerhouse #1 or #2 DSM and radiotagged. The fish will then be released back into the fish bypass system on the same night that radiotagged barge fish are released (approximately 24 h after tagging at Lower Granite Dam). Releases of fish will be made on six dates during the season; ROR fish will be released on the last three dates when maximum passage of Snake River migrants are at Bonneville Dam. All chinook greater than 20 g collected at Lower Granite Dam will be tagged except for those with large open wounds or which are obviously moribund. The same selection criteria when tagging barged fish will be used when tagging ROR fish, and no fish larger than the maximum-sized fish collected at Lower Granite will be tagged.

A subset of fish will be tagged with pressure-sensitive radiotags so that the depth at which fish are migrating may be recorded. The depth preference of migrants may affect their likelihood of being eaten by such predators as Caspian Terns, which feed primarily in the top meter of the water column (Dan Roby, personal communication). Data concerning the depth at which tagged fish migrate will also be collected as individual fish are tracked through the transition to seawater. This information will allow us to determine if migrants are forced closer to the surface as they travel farther into the freshwater lens, or if the fish

readily enters seawater. Depth preference will also be compared to concurrent measurements of the physiology of migrants (see *Task 2a*). We anticipate releasing 5 fish from each type of tagged fish (barged or ROR) with the pressure tag on every release date. The number of individuals with this tag is kept small because these tags will be tracked by boat to get specific migration patterns into saltwater, and only two boats will be tracking so large numbers of expensive depth tags will not be needed.

Fish will be collected on six dates over the migration season so that all aspects of the run are represented. Tagging will occur once every six days, with varying numbers of fish tagged on each day. We are departing from our 1998 strategy of collecting and tagging twice every 8 days; as will be described below, a majority of the fish will be tracked with fixed position dataloggers which do not necessitate splitting releases of fish to gather more data. Practical personnel, management, housing, and monetary concerns also dictate departing from the 1998 release schedule.

Below is a summary table of the proposed 1999 work, indicating numbers of tagged fish for each of the six planned releases. Twenty-five fish will be tagged for each type of fish (i.e., barged or hatchery-reared chinook). Tagging schedule was determined from historical availability of fish at the two dams where tagging will occur. Of the 25 fish tagged for each type, 20 tags will be normal radiotags, and five tags will be pressure-sensitive tags. All barged fish will be tagged at Lower Granite Dam; all ROR fish will be tagged at Bonneville Dam. Total numbers of fish tagged are also given in this summary table:

Release:			1	2	3	4	5	6	
Approximate	Date:		4/20-25	4/26-5/1	5/2-7	5/8-13	5/14-19	5/20-25	T
Chinook	Hatchery	Barged	25	25	25	25	25	25	150
	Hatchery	ROR				25	25	25	75
Total Tags			25	25	25	50	50	50	225

Boats will be used to closely monitor the behavior of individual depth-tagged fish as they traverse the estuary below the Astoria Bridge and enter saltwater. Using information obtained from historical migration speeds adjusted for river discharge rates and aircraft, individual fish will be located and tracked out to saltwater. Data describing detailed migration behavior such as migration speed, holding behavior, and migration route will be collected. The use of depth-sensitive tags combined with the fact that radio signals are attenuated in saltwater will be used to determine the depth and moment when tagged fish enter seawater. Aircraft will be used to determine large-scale movement patterns of yearling chinook within the Columbia River Estuary, to locate individual fish for subsequent detailed tracking by boat, and to check areas of high avian predation (i.e., islands).

To monitor the number of fish that make it to saltwater, we will have a series of data loggers set up in the lower estuary which will continuously monitor fish passing by to give us an accurate estimate of location and survival to that point in the river. This monitoring site will be along the Astoria Bridge, then height of which will provide excellent reception.

Dataloggers will be checked frequently to allow greater sensitivity, ensure proper working condition, recharge power supplies, and download data.

Travel time will be compared among barged or ROR groups released on different dates using a one-way ANOVA; a two-way ANOVA will be used to compare paired releases of ROR fish and barged fish (main treatment effects being migrant type (barged or ROR) and release date). Effects will be considered significant at $\alpha \leq 0.05$. If an effect is significant, means may be compared pairwise by Fisher's Protected Least Significance Difference Test with the significance level again at $P_a \leq 0.05$. The proportion of fish taken by birds will be compared using a Chi-square test comparing groups by release date (for barged fish) and for pairwise comparison of other factors on a single date. This work will provide information concerning migration behavior and survival of juvenile chinook migrants in the Columbia River Estuary. At present we have very limited information concerning detailed migration behavior near the saltwater interface of juvenile chinook salmon. Increased understanding of smolt behavior in the estuary is needed to determine what may be done to minimize rates of avian predation.

Task 1b. Evaluate the effect of run-of-the-river migrant stock origin on migration and survival. The effect of stock origin on ocean distribution and survival will be assessed through the use of radiotelemetry of PIT-tagged sorted fish, collected at McNary Dam. Ten fish from the Snake River and 10 fish from the Columbia River will be tagged for release coincident with passage of barged and ROR salmon released below Bonneville Dam. McNary Dam is in a location to collect smolts from different stock origins, and is the only such dam on the lower Columbia River which will have the capabilities to adequately sort passing PIT-tagged fish. Fish will be tracked as described in *Task 1a*.

Task 1c. Document avian predation rates on radiotagged fish in the estuary. Dataloggers will be placed near the bird colonies at Rice Island and East Sand Island to provide information concerning overall predation rates and the time at which a particular tag arrives at the colony. They will be checked frequently to allow greater sensitivity, ensure proper working condition, recharge power supplies, and download data. The aircraft mentioned in *Task 1a* will also make sweeps over the islands when doing surveys. When possible boats will record any feeding activity of avian predators observed while monitoring tagged fish. Any data we obtain concerning bird predation will be shared with other researchers examining this issue.

Task 1d. Measure or determine physicochemical characteristics of the river and estuary in relation to migrating chinook salmon. Physicochemical water measurements, including salinity (measured at several depths), temperature, dissolved oxygen, channel depth, and secchi depth will be taken while tracking fish in boats in order to determine the immediate environmental conditions associated with the fish. Because movement patterns of individual fish within the estuary appear to be strongly influenced by tide (Schreck *et al.*, 1997; Schreck and Stahl, in prep.), tidal stage and flow of the river will also be taken from public sources for correlation with fish movement and timing of entry into saltwater. Grid

profiles of the estuary will be systematically established while not tracking fish in order to understand the hydrodynamics of the estuary for correlation with fish movement.

Objective 2. Determine the relationship between fish condition (physiological indicators of fish quality) and migration behavior, physicochemical characteristics of estuary, predation susceptibility, and survival. Indices of stress, smoltification, and disease will be measured in yearling chinook salmon collected at Lower Granite Dam prior to barging, at Bonneville Dam after barging, and at Bonneville Dam when tagged ROR fish are released. This will be done in conjunction with collection and release of both barged and ROR fish used for radiotelemetry. These data, along with estuarine physico-chemical data, will be compared to subsequent survival, migration speed estimates, and behavior of radiotagged fish released on the same date. The relationship between degree of smoltification, which is affected by timing of arrival in the estuary (and therefore the decision whether to transport fish), and salinity preference of juvenile chinook salmon will be determined in barged and ROR fish in several ways, in order that monitoring of barged and in-river fish may be predictive of successful ocean entry. First, smoltification of radiotagged fish will be determined prior to release. This will allow behavior and survival of groups of fish at different levels of smoltification to be compared, as well as give an exact relationship for how smoltification is affecting saltwater entry in the estuary for individual fish. Second, on several dates fish are collected and released for radiotelemetry, salinity preference and challenge experiments in a controlled setting will be conducted to compare behavior of barged and ROR radiotagged chinook. The effects of smoltification, disease, and stress of outmigrating juveniles on returning adult spawning populations will also be assessed through a computer-based population model.

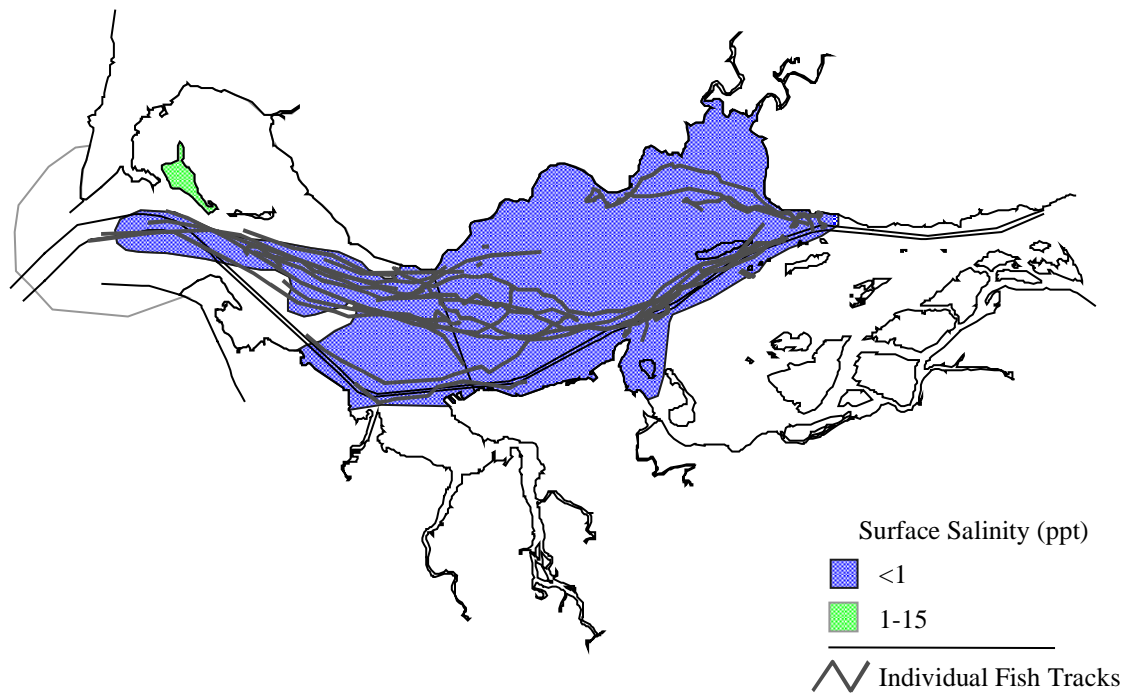
Task 2a. Determine pre- and post-migration physiological status of transported and run-of-the-river chinook smolts at Snake and Columbia River mainstem dams. Health status and smoltification will be determined in juvenile chinook salmon migrants collected at the same time and place as fish tagged to study migration behavior as part of *Tasks 1a* and *1b*. Health and smoltification indicators will then be compared to migration behavior (migration speed, depth preference, holding behavior) and survival in an effort to determine if these indicators are predictive of post-release performance.

Ten fish will be collected from the Lower Granite Fish Facility and from the barge shortly before release for each type of fish (barged or ROR). In this manner the quality of the fish can be determined both before and after the transportation process. Run-of-the-river fish will be collected at Bonneville and McNary Dams. The condition of the fish will be assessed by measuring plasma cortisol (stress; Foster and Dunn, 1974, as modified for use with salmonid plasma by Redding *et al.*, 1984), gill Na⁺/K⁺ ATPase (smoltification; Johnson *et al.*, 1977), and level of BKD infection (disease). Length, weight, and Goede Index (Goede and Barton, 1990) will also be measured as part of fish quality analyses. Coded-wire tags will also be analyzed to determine hatchery of origin of collected individuals.

Factorial analysis of variance (ANOVA) will be used to test for differences in physiological indices among “before” and “after” barging samples and between dates; effects will be considered significant at $\alpha \leq 0.05$. A similar approach will be used to compare paired releases of ROR fish and barged fish (main treatment effects being migrant type (barged or ROR) and release date). Effects will be considered significant at $\alpha \leq 0.05$. If an effect is significant, means may be compared pairwise by Fisher's Protected Least Significance Difference Test with the significance level again at $P_a \leq 0.05$. The proportion of fish taken by birds will be compared between stressed and unstressed individuals using a Chi-square test.

Task 2b. Match physiological data with radiotracking, environmental, and survival data to see relationships between condition and behavior/survival. Data taken from fish sampled for physiology (Task 2a) will be matched with data taken in the estuary under Objective 1. This will be done in several ways: 1) traditional graphical or tabular representation showing relationships between different factors, and 2) spatial mapping with GIS by different and overlapping factors, which has already given us some insight into migration patterns and physicochemical water measures (Figure 1).

Figure 1. GIS-produced map of the Columbia River estuary from river mile 0 - 30. 1998 fish migration paths are indicated in red and overlaid onto the seasonal salinity profile for the estuary at 0-4 m depth, the level depth-tagged fish were found while being tracked with boats. Note the propensity for fish to apparently remain in freshwater as long as possible and existence of large-scale migration patterns. Depths lower than 4 m were more saline.



Task 2c. Determine smoltification status of individual radiotagged fish and compare to subsequent behavior and survival. In order to better correlate the degree of smoltification with individual chinook which have actually been tagged and traveled to the estuary, we will determine degree of smoltification at the time of tagging. Smoltification level will be matched to migration, performance, and survival for individual fish and compared between different levels. Degree of smoltification will be determined in two ways: 1) by taking a gill clip of each fish while under anesthetic for later determination (more accurate), and 2) by measuring reflectance in a light box and estimating condition factor, for initial grouping (less accurate). Initial groups will be used to prioritize tracking in the estuary so we can gather data at all degrees of smoltification. This will be done on two dates (releases #3 and 5) for all chinook salmon tagged. This will provide direct measures of smoltification for fish actually tracked in the estuary (*Task 1a*).

Task 2d. Perform direct tests of the relationship between smoltification, bacterial kidney disease, saltwater entry behavior, and saltwater survival in a controlled situation. The relationship between degree of smoltification and salinity preference of juvenile chinook salmon will be determined in a controlled experiment for barged fish on three dates during the early, middle, and late portions of the migration season. Chinook will be collected on dates that radiotagged fish are collected or released for radiotelemetry. Barged fish will be collected as the barge locks through at Bonneville Dam. On the last two dates we will also test ROR fish obtained from the sample collected by NMFS smolt monitoring personnel at Bonneville Dam. Fish will be transported to a field test site located near Bonneville Dam to minimize transportation stress on the fish. Conducting controlled experiments at a field laboratory site near Bonneville Dam, but away from the project, allows for more controlled studies due to less disturbance (noise, vibration, etc.) of the test animals, which is especially important for measuring behavior. It also minimizes transportation stress that might be incurred if the tests are done at a location not near Bonneville Dam (i.e., Oregon State University, Corvallis).

Upon arrival at the test site, fish will be placed in a 200L rectangular tank and allowed to acclimate for 24 hours. After this period saltwater (32 ppt) will be infused into the bottom of the tank to establish a vertical salinity gradient in which the top half the tank is freshwater and the lower half is saltwater. One hour later the vertical position of individual fish will be determined. Each test will be conducted with 12 fish; on each date two replicate tests will be conducted for each group (barged and ROR, hatchery and wild). At the completion of the test the freshwater will be drained from the tanks and the fish will be forced into saltwater for 24 hours (Blackburn and Clarke, 1987). After this time, survival will be noted and fish will be sacrificed for measurement of fish condition as described in task 2. Behavioral response to salinity will then be compared with physiological indices of smoltification and to the behavior of radiotagged cohorts as they travel through the estuary and into saltwater. The dates and numbers of fish collected for these tests are:

Release:		1	2	3	4	5	6	
Approximate	Date:	4/20-25	4/26-5/1	5/2-7	5/8-13	5/14-19	5/20-25	T
Chinook	Hatchery Barged			24		24	24	72

	Hatchery	ROR				24	24	48
Total Tags			0	0	24	0	48	48
								120

Task 2e. Develop and validate a computer model incorporating all of the factors associated with smolt survival in the estuary as measured by returning adult spawners. Ultimately, the goal of this research is to increase survival of outmigrating juvenile salmonids so they can contribute in greater numbers to the returning adult spawning population. In order to understand how the survival of juveniles, as affected by stress, smoltification, disease, and predation, through the estuary influences returning spawner population, we will add a detailed outmigrating juvenile stage to an existing life-history model for salmonids, which is being used to predict adult populations. This model was originally developed for the Governor of Oregon's Coastal Salmon Restoration Initiative (CSRI) by Nicholson and Lawson. Dr. Gretchen Oosterhout (Decision Matrix, Inc.) has recently advanced this model, applied it to the Snake-Columbia River system, and incorporated variables we suggested were critical for the lower Columbia River estuary, including avian predation and smolt quality. We will work with her to further develop the model, validate it, and then plan and run simulations that will provide understanding of how outmigrating juvenile survival affects numbers of returning adult spawners, and, in turn, determine effects of management decisions concerning transportation, as well as avian predators, on adult chinook returns.

Limitations

- High flows may make tracking individual fish through the transition to seawater more difficult by pushing the freshwater lens past the Columbia River mouth. Tracking efforts in general may be suspended in periods of extremely bad weather, but our experience indicates that we will have no major problems. The number of individual fish that can be followed in detail is limited by the number of boats and crew available, but data collected by aircraft and at the fixed monitoring station is intended to partially compensate for this limitation by providing less detailed information on more individuals. The fixed monitoring station will be based on existing structures which should provide adequate coverage of the entire migration area; however, the range of the dataloggers is dependent on variables such as fish depth, saltwater presence, and interference, so the possibility of not logging fish that pass exists.
- McNary Dam, once the PIT-tag diverter at McNary Dam must be operational in order for *Task 1b* to be accomplished.
- Availability of migrants may be limited, especially late in the migration season.
- Live fish handled for smoltification determination may undergo increased stress from the increased handling; this may affect their survival and performance.
- Lab results cannot be directly extrapolated to the field situation, but will provide information that can be used to evaluate field observations obtained in the Columbia River estuary.
- Model results cannot account for all variables present in real field situations, but will provide information that can be used to guide and evaluate field observations obtained in the Columbia River estuary.
- Our activities at dams and on barges should not impact any other research.

g. Facilities and equipment

Laboratory work will be done at field sites to be determined (housing near Bonneville Dam or possibly the fish hatchery at Bonneville Dam). Field work will be done at the Lower Granite Dam Juvenile Fish Facility, Bonneville Dam First and Second Powerhouse DSMs, McNary Dam fish facility, on transport barges, and in the Columbia River estuary. We are equipped already with two boats and several backups for radiotracking, as well as the necessary equipment for day or night tracking (GPS with differential beacon receivers, radar units, radios, radio receivers, depth finders, spotlights, and safety equipment). Work vehicles are also at our disposal.

h. Budget

Work will be performed over two years in order to account for annual variation. The number of personnel needed is based on having, for a day's work, 2 people on each of two boats and in the aircraft (=6), 1 person in another boat managing dataloggers and water measurements, and 3 people doing tagging, physiology, and experiments (10 total). A number of special expenses are required for this work:

- Radiotags: We anticipate the purchase of 180 radiotags and 45 pressure-sensitive tags (see task #1 "description of study" text table).
- Aircraft flight time: This is required for locating radiotagged fish, especially within the estuary, due to the large distances that must be covered and the limited range of the radio transmitters. (Elevating the radio antenna above the water greatly increases the range at which the tag can be detected.)
- Boat charter time: On days when radiotagged fish are passing through the estuary and water surface conditions are dangerous for our smaller boats (20') but not for a larger boat, we will charter a boat to track fish.
- Lotek radiotag receivers/dataloggers: In order to monitor for fish in the lower estuary, we will need to refurbish and upgrade ~7 of our current units will also need to be refurbished.
- Water quality probe: One additional probe is required to double our ability to make field measurements of water quality parameters during tracking of fish through the estuary.
- Laptop computer: A laptop computer which will run for several hours on battery power is needed to download dataloggers in the field, so we do not need to purchase extra Loteks to switch out in order to download them. All current OCFRU laptops have no battery life and must be run in the field off of immobile electric converters (DC to AC) and car batteries.
- Travel expenses include housing and vehicle (approximately 5 vehicles total) use for two separate groups, one of which will have three boats, for three months.
- Off-campus indirect rates are used because field work on the Columbia and Snake Rivers will be conducted from 15 March through 21 June each year. Prior to actual release of fish, the dates of which are noted previously, we must conduct training of

personnel in the following areas: US Department of the Interior boat and aircraft safety classes, first aid and CPR, Bonneville Dam orientation, radiotelemetry technique and equipment training, and physiological technique and equipment training. Work through June consists of tracking fish, taking water physicochemical data, breaking down remote sensing field sites, organizing, entering, and analyzing data from field work, and cleaning and packing field equipment.

Section 9. Key personnel

Carl B. Schreck

Project	<u>Principal Investigator</u>	
Duties	<ul style="list-style-type: none"> • Oversee all aspects of project management 	
Expertise	Research in environmental physiology of fish including stress, health and reproductive quality, and behavior of salmonids. Project management. Publication.	
Current Position	<u>Leader</u> , Oregon Cooperative Fish and Wildlife Research Unit, Biological Resources Division-U.S.G.S., and <u>Professor</u> , Dept. of Fisheries and Wildlife, Oregon State University. Corvallis, Oregon	
Education	University of California, Berkeley A.B.-Zoology, 1966	Colorado State University M.S.-Fisheries Science, 1969 Ph.D.-Physiology/Biophysics and Fisheries, 1972
Experience	<ul style="list-style-type: none"> • 25 years research in Columbia River system on juvenile and adult salmonids in streams, rivers, reservoirs, dams, and estuary • 30 years research and project management leading to nearly 200 publications • Editor or editorial board of 5 scientific journals; presently <i>General and Comparative Endocrinology</i>, <i>Diseases of Aquatic Organisms</i>, and <i>Aquaculture</i> • Formerly Assistant Professor- Fisheries, Virginia Polytechnic Institute and State University 	
Recent Publications	<p>Schreck, C.B., B.L. Olla, and M.W. Davis. 1997. Behavioral responses to stress. p. 745-170. <u>In</u>: G.W. Iwama, J. Sumpter, A.D. Pickering, and C.B. Schreck (eds.). Fish stress and health in aquaculture. Cambridge University Press., Cambridge.</p> <p>Schreck, C.B. 1996. Immunomodulation: endogenous factors. p. 311-337. <u>In</u>: G.W. Iwama and T. Nakanishi (eds.). Hoar and Randall's Fish Physiology, vol. 15. Academic Press, New York.</p> <p>Contreras-Sanchez, W.M., C.B. Schreck, M.S. Fitzpatrick, and C.B. Pereira. 1998. Effects of stress on the reproductive performance of rainbow trout. (<i>Oncorhynchus mykiss</i>). Biol. Reprod. 58:439-447.</p> <p>Maule, A.G., R. Schrock, C. Slater, M.S. Fitzpatrick, and C.B. Schreck. 1996. Immune and endocrine responses of adult chinook salmon during freshwater immigration and sexual maturation. Fish and Shellfish Immunol. 6:221-233.</p> <p>Davis, L.E. and C.B. Schreck. 1997. The energetic response to handling stress in juvenile coho salmon. Tran. Amer. Fish.Soc. 126:248-258.</p>	

Thomas Stahl

Project	<u>Project Leader</u>	
Duties	<ul style="list-style-type: none"> • Oversee and organize all OCFWRU activities • Coordinate work between cooperating groups • Perform administrative and reporting requirements for the project 	
Expertise	Current and past experience as a project leader and in aquatic and fisheries research have provided necessary skills and knowledge to perform as project leader and coordinator for this integrated telemetry and physiology work.	
Current Position	<p>Oregon Cooperative Fish and Wildlife Research Unit (OCFWRU) Oregon State University, Dept. of Fisheries and Wildlife. Corvallis, OR <u>Project Leader/Faculty Research Assistant</u> (1.0 FTE). January 1998 - present</p> <ul style="list-style-type: none"> • prepares and completes proposals, reports, manuscripts, and presentations • designs and analyzes research • hires, trains, organizes, and supervises personnel • performs budget administration • coordinates and interacts with a variety of other agencies • prepares for and oversees field and lab work involving fish radiotelemetry and physiology 	
Education	<p>The Ohio State University Columbus, OH April 1991 - September 1993 Master of Science in Aquatic Ecology Advisor: Roy A. Stein</p>	<p>University of Notre Dame Notre Dame, IN August 1986 - January 1990 Bachelor of Science Major: Biological Sciences/Ecology</p>
Experience	<p>UMass Dept. of Landscape Architecture and Regional Planning. Amherst, MA <u>Research Assistant</u>. September 1996 - May 1997</p> <p>The Ohio State University, Aquatic Ecology Laboratory. Columbus, OH <u>Research Associate</u>. January 1995 - August 1996 <u>Computer Administrator</u>. January 1995 - August 1996 <u>Lecturer and Teaching Assistant</u>. January 1995 - April 1995 <u>Graduate Research Associate/Project Leader</u>. April 1991 - September 1993</p>	
Certification	<p>U.S. Dept. of the Interior, Motorboat Operator Certification Course, April 1998 U.S. Dept. of the Interior - OAS, Basic Aviation Safety Course (B-3), April 1998 American Red Cross, Standard First Aid, March 1998 American Red Cross, Adult CPR, March 1998 Oregon State University, Radiation Safety Course, September 1998</p>	
Relevant Job Report	<p>Schreck, C.B. and T.P. Stahl. In Prep. Evaluation of migration and survival of juvenile salmonids following transportation. Draft Annual Report 1998, Project MPE-W-97-4. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.</p>	
Recent Publications	<p>Stahl, T.P., G.P. Thiede, R.A. Stein, E.M. Lewis, M.R. Austin, and D.A. Culver. 1996. Factors affecting survival of age-0 saugeye <i>Stizostedion vitreum vitreum</i> X <i>S. canadense</i> stocked in Ohio reservoirs. North American Journal of Fisheries Management 16:378-387.</p> <p>Stahl, T.P., and R.A. Stein. 1994. Influence of larval gizzard shad (<i>Dorosoma cepedianum</i>) density on piscivory and growth of young-of-year saugeye (<i>Stizostedion vitreum vitreum</i> X <i>S. canadense</i>). Canadian Journal of Fisheries and Aquatic Sciences 51:1993-2002.</p>	

Section 10. Information/technology transfer

This work will provide information that will be used to make recommendations for managing the Columbia River hydrosystem so that mortality of juvenile salmonids is minimized. Results will be presented at meetings as requested by Bonneville, at professional meetings, and through publications in peer-reviewed literature.

Congratulations!